NOAA National Centers for Environmental Information Topo-Bathymetric Digital Elevation Modeling: Puerto Rico and US Virgin Islands

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Introduction

This report briefly describes the creation of tiled Digital Elevation Models (DEMs) developed for the islands of Puerto Rico and the US Virgin Islands (USVI) during winter 2018-19 by the NOAA National Centers for Environmental Information (NCEI; Fig. 1). This work was funded by the National Weather Service under the auspices of the COASTAL Act to improve NOAA's storm surge mapping and modeling capabilities.

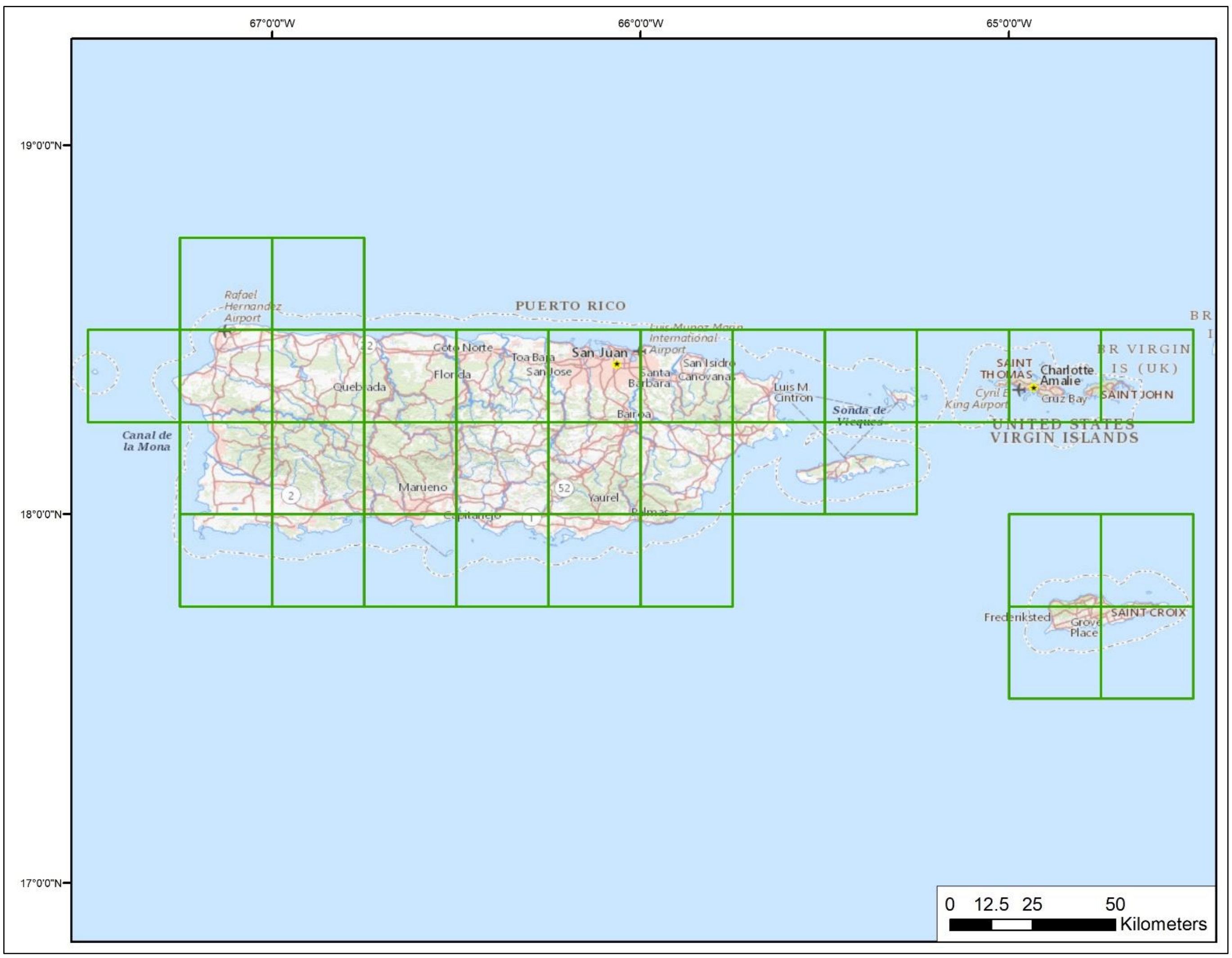

Figure 1. Spatial Extent of the 2019 NOAA NCEI Puerto Rico & US Virgin Islands Tiled DEMs.

Thirty-one tiled DEMs were created in the area of interest. The DEMs tiles integrate topography and bathymetry data into a seamless product. The DEM tiles represent the best available coastal elevation data at the time of their creation. The utilization of a tiling scheme in developing the DEMs is designed to improve data management during source data processing as well as facilitate targeted DEM updates as new source data are acquired and become available. The DEMs were developed according to the specifications found in Table 1.

Table 1. Specifications for the Puerto Rico/USVI DEM tiles.

Horizontal Datum	North American Datum of 1983 (Geographic CRS)
Vertical Datum	Puerto Rico Vertical Datum of 2002 (PRVD02) Virgin Islands Vertical Datum of 2009 (VIVD09)
Vertical Unit	Meter
Cell Size	1/9 arc-second

Data Sources and Processing

The DEM tiles are derived from a variety of disparate elevation datasets collected using a range of survey technologies. These data were collected between 1900-2018. Multiple pre-processing steps are necessary to standardize the source data in preparation for DEM generation.

All source data (Table 2) used in the creation of the DEM were converted to a common horizontal of NAD83 using various Geospatial Data Abstract Libraries (GDAL) utilities. The vertical datum of bathymetric datasets referenced to Mean Lower Low Water (MLLW) were converted to the Puerto Rico Vertical Datum of 2002 (PRVD02) or the Virgin Islands Vertical Datum of 2009 (VIVD09) for consistency with topographic data already referenced to PRVD02/VIV09 using the NOAA VDatum software. The Geoid12B geoid model was used in all vertical datum transformations.

All data were converted to a common data format (ASCII xyz) in preparation for gridding. All bathymetry data obtained in raster format was resampled to a target spatial resolution of a 1/3 arc-second using a bilinear resampling algorithm, then converted to ASCII xyz using GDAL. Topography data obtained in raster format was resampled in a similar manner, although with a target resolution of 1/9 arc-second. Data obtained as a "point cloud" were converted to ASCII with no intermediate processing. All data was reviewed and evaluated for internal and external consistency with adjacent data. Anomalies were identified through visual inspection and removed with manual (area-based editing in a desktop GIS) and automated filtering.

MB-System's 'mbgrid' utility was used for interpolation and gridding. A tensioned thin-plate spline algorithm was used to interpolate depth values in pixels within the DEM extent that were unconstrained by elevation measurements. Constrained pixels were assigned a final elevation value based on the Gaussian weighted average of the input source elevation measurements. Datasets were preferentially weighted to minimize the influence of lesser quality (e.g. older and/or low resolution) data.

An initial bathymetric surface was created at a spatial resolution of 1/3 arc-second (see Carignan et al., 2011 for a detailed description of the process). The maximum elevation value of this grid was constrained at -0.05 m, effectively ensuring all submarine areas an elevation value below the adjacent topography. Given the disparate nature of the source bathymetric data, a 2-D Gaussian convolution filter was applied to the bathymetric surface in order to minimize discontinuities between adjacent datasets and smooth any persistent anomalies. The resultant smoothed bathymetry was then resampled to 1/9 arc-second and merged with gridded topography data to create the final integrated DEM product.

No quantitative analysis was performed to assess the accuracy of the DEMs, although this continues to be an area of active research at NCEI (see Amante, 2018; Amante and Eakins, 2016).

Table 2: Data sources used in DEM development. Blue highlighting indicates a bathymetry source, red indicates a topographic-bathymetric source and green indicates a topographic data source.

Dataset Source	Data Type	Acquisition/ Creation Date	Data Density/ Spatial Resolution	Original Vertical Datum	Notes
NOAA Office of Coast Survey (OCS)	Hydrographic soundings (ASCII point data) & survey specific bathymetric DEMs (grid)	1900-2016	Variable	Mean Lower Low Water (MLLW)	See Appendix A for listing of high-resolution products used
NOAA NCEI	Multibeam sonar (binary point)	1985-2017	Variable	Instantaneous Sea Level (uncorrected)	Multibeam Bathymetry Database (MBBDB)
NOAA NCEI	Composite bathymetry DEM (grid)	2014	1 arc-second (~30 m)	Mean High Water (MHW)	USVI Coastal Digital Elevation Model Version 2
NOAA National Centers for Coastal Ocean Science (NCCOS)	Composite bathymetry DEM (grid)	2013	4 m	MLLW	Northeast Puerto Rico Bathymetry Model
U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center	Composite bathymetry DEM (grid)	2014	150 m	Instantaneous Sea Level (uncorrected)	Open-File Report 2013-1125
USGS St. Petersburg Coastal and Marine Science Center	Bathymetric lidar DEM (grid)	2014	2.5 m	VIVD09	EAARL-B Submerged Topography—Saint Thomas
U.S. Army Corps of Engineers (USACE) Jacksonville District Office	Singlebeam sonar (ASCII point)	2018	Variable	MLLW	San Juan and Ponce Harbor surveys
NOAA National Geodetic Survey (NGS)	Airborne topo-bathy lidar (binary point)	2015, 2016	> 2 pts/m^2	PRVD02	Puerto Rico Shoreline Mapping
USACE Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX)	Airborne topo-bathy lidar (binary point)	2016, 2018	> 2 pts/m^2	PRVD02	2015 National Coastal Mapping Program; 2018 USACE FEMA
NOAA Office for Coastal Management (OCM)	Topographic lidar (grid)	2013	3 m	VIVD09	USVI Topographic Lidar project
National Aeronautics and Space Administration (NASA)	Shuttle radar topography (grid)	1994	1 arc-second (~30 m)	EGM96 (Earth Gravitational Model of 1996)	SRTM Version 2.1
USGS 3D Elevation Program (3DEP)	Topographic lidar (binary point)	2016	> 2 pts/m^2	PRVD02	Commonwealth of Puerto Rico Lidar Project

References

Amante, C.J., 2018. Estimating Coastal Digital Elevation Model Uncertainty. *Journal of Coastal Research*, 34(6), pp. 1382-1397.

Amante, C.J. and Eakins, B.W., 2016. Accuracy of interpolated bathymetry in digital elevation models. *In*: Brock, J.C., Gesch, D.B., Parrish, C.E., Rogers, J.N., and Wright, C.W. (eds.), *Advances in Topobathymetric Mapping, Models and Applications. Journal of Coastal Research*, Special Issue, No. 76, pp.122-133.

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Appendix A: NOAA Bathymetry Attributed Grids Used in DEM creation

H11557	W00182
H11558	W00183
H11559	W00184
H11560	W00199
H11561	W00200
H11562	W00207
H11563	W00212
H11564	W00213
H11565	W00214
H11566	W00215
H11567	W00216
H11808	W00221
H11809	W00222
H12171	W00231
H12172	W00233
H12271	W00234
H12272	W00235
H12273	W00246
H12639	W00247
H12756	W00296
H12757	W00297
H12935	W00298
H12936	W00324